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# ESD: Another kind of lethal contaminant?

## *Drive Makers Have to Stand Guard Against a New Enemy: Static Electricity*

Douglas Cooper and Rob Linke, *The Texwipe Company*

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As recently pointed out in this magazine, it only takes about 25 V of static electricity to functionally destroy an MR head.[1] Indeed, for the most part, the poor yields for MR heads (reportedly between 18% and 25%) are attributed to electrostatic discharge (ESD).[2] Moreover, trends in MR head design (i.e., the use of thinner films, higher current densities, and narrower structures) — not to mention the advent of more sensitive giant magneto-resistive (GMR) technology — seem to indicate that static electricity will pose an even greater threat in the near future.[3] So, it's clear that the drive industry will have to learn how to deal with this "energy contaminant" as they have with other contaminants in the past.

There's a catch, though: Care must be taken to ensure that standard contamination-control measures do not compromise ESD management and vice versa. Garments that are cleaner than the driven snow may pose an unsuspected threat if, like wipers and swabs, they are made of pure polymers on which static charges tend to accumulate. Such problems can be avoided by choosing materials that are neither insulators (which prevent the static charge from being transferred to other objects, resulting in a buildup of static electricity) nor conductors (which allow the charge to dissipate so rapidly that an electrostatic discharge occurs).

Better choices are intermediate materials that are "static dissipative"—that is, materials that allow the charge to gradually drain to ground. Static dissipative fabrics, for example, are used in dry wipers to minimize static buildup or discharge when cleaning tabletops and equipment that are not grounded.

Such fabrics can be made out of various fibers. One option is to use moderately conductive polymer fibers. The technology is well developed; however, it's also expensive.[4]

Polymer alloys are yet another choice; in fact, they are already being used in some swab handles and component trays. The conductive and insulative materials are mixed on the molecular level, forming "inherently dissipative polymers."[5] And, of course, carbon or metal fibers can be used, though they are less favorable since they tend to abrade and release conductive debris. Hard coatings could resist abrasion.

### Measuring Resistivity

Materials used in ESD-sensitive areas are often tested for surface or volume resistivity. Figure 1 shows the basic elements for measuring surface resistance. A constant DC voltage is applied by electrodes to the material being tested, and the current (*I*) along the surface is measured, from which the resistance ($R = V/I$) is calculated. Knowing $R$ and the geometry, and assuming that all the current travels along the surface, surface resistivity can be measured.

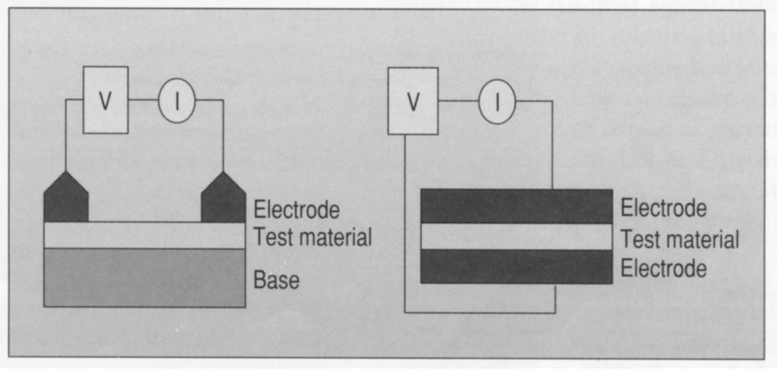

**Fig. 1**. *To determine surface resistivity (left), a voltage is applied by electrodes across the test material. To determine volume resistivity (right), the test material is sandwiched between two electrodes, which act as a capacitor*.

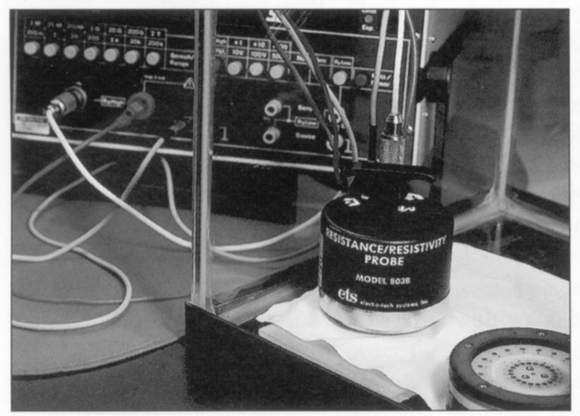

**Fig. 2**. *Setup for measuring surface resistivity. Insulating base, test material, surface resistance probe, and probe calibration fixture are in a chamber where the temperature and humidity is closely controlled*.

Measuring the resistivity of homogeneous materials is fairly straightforward. However, if many parallel conductive wires are added to the surface of the fabric, resistance depends on both the orientation and the spacing of the wires and the test electrodes. Turning the fabric over would insulate the wires from the electrodes, resulting in a higher surface resistivity. If a static charge is placed on the fabric, the speed at which it dissipates or spreads over the fabric depends on where the charge was placed in relation to the wires. Large spacings between wires yield “hot spots” of built-up charge. The relative humidity also needs to be specified (and controlled), since adsorbed moisture greatly affects surface resistivity. Some anti-static treatments rely on absorbing water vapor and may be ineffective when the relative humidity is lower than 50%.

Figure 1 shows how volume resistivity, $\rho_v$, is measured. A voltage is applied across two plates or electrodes (the test specimen is between the two plates). The resistance, $R$, is determined from the ratio of the voltage to the current ($R = V/I$). Alternatively, the plates can be given an initial voltage, $V_0$, with the decrease in the voltage measured over time. The resistance is related to the volume resistivity, $\rho_v$, as follows: $R = \rho_v (s) / A$, where $s$ is the spacing between the parallel plates and $A$ is the contact area.

Volume resistivity is a bulk phenomenon, dependent on all the material not just the surface, that is less sensitive than surface resistivity to the adsorption of conductive molecules. Ignoring conduction through voids, volume and surface resistivities are proportional to 1/(1-*void fraction*). Surprisingly, resistivity for some insulating materials is time-dependent: Longer times yield higher resistivity values that, according to the ASTM, are proportional to time to some power between 0 and 1. We have observed this in measuring the surface and volume resistivities of polyester wipers and polyester-based sheet materials—volume resistivities after 10 minutes were about twice as high as those after one minute, while surface resistivity was proportional to time to the 0.3 to 0.4 power. For some insulators, resistance diminishes as the applied voltage gradient increases, so *R* is really *R(V/s,t)*, a function of voltage gradient and time.

## ZAP: GLOSSARY OF ESD TERMS

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| **Antistatic** | Usually refers to the property of a material that inhibits triboelectric charging. |
| **Corona** | The production of positive and negative ions in a gas by a very localized high electric field. |
| **Dielectric strength** | The maximum electric field that a dielectric can sustain. |
| **Discharge time** | The time necessary for a voltage (due to an electrostatic charge) to decay from an initial value to some arbitrarily chosen final value. |
| **Electrostatic discharge** | The rapid, spontaneous transfer of electrostatic charge induced by a high electrostatic field. |
| **Faraday cage** | A conductive enclosure that attenuates a stationary electrostatic field. |
| **Inductive charging** | The transfer of an electric charge to an object when it is momentarily contacted to ground in the presence of an electric field. |
| **Static dissipative** | A property of a material having a surface resistivity of at least 1 × $10^5$ ohm/square or 1 × $10^4$ ohm-cm volume resistivity but less than 1 × $10^{12}$ ohms/square surface resistivity or a 1 × $10^{11}$ ohm-cm volume resistivity. |
| **Surface resistivity** ($\rho_s$) | For electric current flowing across a surface, the ratio of DC voltage drop per unit length to the surface current per unit width. |
| **Topical antistat** | An antistat that is applied to the surface of a material for the purpose of making the surface static dissipative or to reduce triboelectric charging. |
| **Triboelectric series** | A list of materials arranged to indicate that one can become positively charged when separated from one farther down the list. [Various factors can change this order in specific cases.] |
| **Voltage suppression** | Reduction of the voltage (*V*) of a charged object by increasing its capacitance (*C*) rather than by decreasing its charge (*Q*), in accordance with the formula $V = Q/C$. [This usually occurs by bringing the charged object closer to ground.] |
| **Volume resistivity** ($\rho_v$) | The ratio of the DC voltage per unit thickness to the amount of current per unit area passing through a material … in ohm-centimeters. |
| **Zap** | See electrostatic discharge. |

Based on ESD Association glossary (ESD-ADV 10.0-1994).

The volume resistivity of untreated polymer fabrics is approximately $10^{14}$ ohm-cm, which is very insulative. In comparison, the resistivity of ultra-pure water is $18 \times 10^{6}$ ohm-cm, or seven orders of magnitude less. Liquids containing more than trace amounts of water can be expected to make fabrics static-dissipative. Dry fabrics can develop sufficient charge to produce an electrostatic discharge. Some cloths carry a positive charge; some can become negatively charged. They may discharge to the atmosphere through corona discharge. It has also been established that positive coronas are qualitatively different from negative coronas.

## Measuring Static Decay

"Static decay" can be measured using various tests. The samples are raised to a high voltage (e.g., +/- 5 kV DC), then grounded while the "voltage decay" (actually, the electrostatic field) is measured over time by a noncontacting electrostatic field meter. The time constant is determined by the capacitance and resistance of the sample and the circuit. (Capacitance is a function of geometry, while resistance is some combination of surface and volume effects.)

Homogeneous materials can be tested in this manner, but materials that are not homogeneous (e.g., fabrics composed of conductive and nonconductive fibers) are much harder to measure and to interpret correctly. As noted recently, the Electronic Industries Association (EIA) 541 static-decay test monitors the electrical field, not the charge itself. Thus, a conductive layer in a material collapses the field by capacitive coupling or by voltage suppression in a deceptively brief time.[6, 7] The remaining hidden charge, or cryptocharge, may cause ESD damage.

A charge can also be applied by tribocharging. But an ESD Association Advisory (ADV11.2-1995) notes that no one test currently available can predict general tribocharging properties for a specific material. The amount of charge that a material accumulates depends on the second charging material (as well as other variables). In many cases, test data do not relate to actual use conditions.

Two other points should be made: 1) that the resistance of dielectric materials often depends on the duration of the application of the voltage difference (see ASTM D 257-93, for example) complicates any interpretation of static decay behavior; and 2) that the resistance of dielectrics often depends on the voltage gradient and thus is a function of the size of the sample and on the time history of the decay.

The following is a summary of research conducted by the British Textile Technology Group.[8] The British group measured surface resistivity, charge decay, and spark discharge (to conducting spheres of various sizes) of plain weave fabrics made from polyester and nylon yarns. Polyester surrounding a conductive core material was found to be much more insulative than either conductive material sand-wiched between polyester or nylon covered with a conductive coating. The polyester-conductive core sample failed the charge decay rate test, while some of the nylon samples passed the charge decay test. When conducting spheres were brought close to these fabrics, a discharge occurred—except when the conductive fibers were grounded. Clearly, all these fabrics pose some ESD threat.

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***Douglas Cooper*** *is director of contamination control at the Texwipe Company in Upper Saddle River, NJ. He received a PhD in applied physics from Harvard University*.

***Rob Linke*** *is director of marketing at the Texwipe Company. He received a BSME and a BA in economics from Tufts University*.